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Native speech plasticity in the German-English late bilingual Stefanie Graf:

A longitudinal study over four decades

Esther de Leeuw

Queen Mary University of London

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Abstract

The purpose of this study was to expose the trajectory of native speech plasticity in the context of late bilingualism through analysis of spontaneous speech of Stefanie Graf (SG) over four decades.

With regard to segmental variables, results showed a significant lowering of F2 in /l/, suggesting darkening of the German lateral under the influence of English as a second language (L2). F2 significantly increased in /i/, indicating a more front pronunciation, as predicted due to English L2 acquisition. There was also a significant decrease in F1 of /l/, as well as of /i/, but a significant increase in the F1 frequency of /a/, suggesting widening of the vertical vowel space, potentially due

to increasing age. Regarding prosody, there was a significant decrease in pitch level and narrowing of pitch span over time, as expected with increasing age, and an increase in average *maximum f0* over time, possibly as a result of English L2 acquisition of prosody.

These findings suggest that native speech remains plastic post adolescence throughout adulthood, here proposed to be evidenced through a result of acquisition of L2 counterparts in late bilingualism, and that such changes are intertwined with natural biological speech developments over the lifespan.

The main objective of the present research was to expose the trajectory of plasticity in native speech over the course of four decades in the native German speech of Stefanie Graf (SG) from youth (12 years of age) to mid adulthood (48 years of age). This objective was set to pursue the questions of whether and how native speech remains plastic post adolescence within the context of late bilingualism. Indeed, we know very little about the extent to which speech changes and develops throughout the lifespan post childhood, and what we do know comes largely from studying monolinguals.

Monolingual longitudinal research into speech plasticity

Seminal longitudinal research examining the Queen's Christmas speeches shows that phonetic norms change in adulthood in monolinguals (Harrington, 2006; Harrington, Palethorpe, & Watson, 2000a, 2000b). In Harrington et al.'s research, one of the many findings was that the final vowel of words like *happy* became more tense in the Queen's Christmas speeches over an analysis window of 50 years (so-called happY-tensing). Based on their results, they proposed that in Received Pronunciation (RP), the KIT and happY vowels had undergone phonetic raising, and that the Queen participated in these sound changes (Harrington, 2006). As underscored by Labov, "[t]he significance of Harrington's result [...] rests on his strengthening the case for adult change rather than stability" (2006, p. 501). Indeed, he was able to show that "one individual—who might have been expected to be the most resistant to changes in the community pattern—did in fact absorb community change in her own speech" (Labov, 2006, pp. 501–502).¹

¹ Note, however, that the style of speech used by the Queen in her scripted Christmas speeches was not necessarily representative of *her* "vernacular", as defined by Labov (1997, p. 168). Helen Mirren notes the difference in the Queen's speech styles in an interview regarding her role as the Queen: "I mean, she has a voice for her speeches, and then she has her own voice, and they are really quite different, and it was very hard to get to the real voice because we hear it so infrequently" ('Interview with Helen Mirren', n.d.). This is important to note because it may be that the speech analysed in her Christmas speeches was representative of her formal speech, which is becoming more like the *community's* vernacular.

Moreover, longitudinal research into monolinguals also indicates speech plasticity in adulthood as a result of new dialect acquisition in individuals who have moved to a new dialect area. A study investigating vowel changes in three sessions over two years among London students from the Midlands, UK, where the local accent is classified as a variety of northern English (Evans, 2005; Wells, 1982), showed that the subjects' accents became more like Standard Southern British English (SSBE) revealing plasticity in early adulthood. However, there were differences in the amount and direction of accent change: although the majority of subjects were rated as sounding more 'southern' after two years than when they were first recorded, in a minority, there was only a very slight change in accent; three subjects were rated not to have changed their accent at all; and one subject was judged to have a more 'northern' accent at the final testing session than when she first moved to London. Similarly, Sankoff (2004) carried out an impressionistic study of dialect change over the lifespan in two speakers who were recorded from childhood to mid-adulthood. Until the age of 16 both speakers lived in northern England, where the front [a] is produced in BATH words and [ʊ] in both *could* and *cud*. Both speakers began to distinguish *could* and *cud* words after moving to the south of England. Only one speaker, however, inconsistently produced non-northern [ɑ:], again suggesting that speech plasticity takes place in adulthood as a result of new dialect acquisition, but is variable between speakers. Furthermore, in the case of the broadcaster and journalist Alistair Cooke, who moved to the United States from England in early adulthood, it was found that he evidenced a more American-like pronunciation in mid-life, but then reverted back to a more British English-like pronunciation in late adulthood, although he continued to live in the United States at that time (Reubold & Harrington, 2015, 2017). Such longitudinal dialect acquisition studies indicate that new dialect features are indeed acquired by adult speakers, although the degree of change in native dialect varies between and within participants, thereby supporting findings from cross-sectional dialectal research (see Nycz, 2015 for an overview and also e.g. Munro, Derwing, & Flege, 1999; Nycz, 2013; Shockey, 1984).

Additionally, some research has honed in on natural biological changes which speech undergoes in adulthood, i.e. neither as a result of sound changes in the community nor as a result of new dialect acquisition. For example, a further longitudinal study of Queen Elizabeth II, as well as of Margaret Thatcher, and Margaret Lockwood (a popular British actress in the 1930s and 1940s), investigated speech developments in mid-adulthood (mid 30's) versus late adulthood (mid 60's to early 70's) (Reubold, Harrington, & Kleber, 2010). It was found that both fundamental frequency (f_0) and F1 followed a generally decreasing trajectory with increasing age, but that F2 and F3 evidenced no systematic changes over time, except in Lockwood who displayed a decrease in F3. The results of this longitudinal analysis were interpreted to be consistent with other cross-sectional investigations into biological aging effects by showing a decrease in f_0 and F1 with increasing age in female voices (Linville, 1996; Linville & Rens, 2001). Such decreases in formant values due to aging have been attributed to a lengthening of the vocal tract, caused by a lowering of the larynx and of the tracheobronchial tree and lungs (Laver & Trudgill, 1979; Linville & Rens, 2001), although these explanations are not conclusive (see e.g. Reubold et al. 2010 for a discussion). In relation to the current investigation, it is worth noting that a later age range (34-70 years of age) was investigated in the Reubold et al., 2010 study, whereas the recordings of SG were from ages 12-48, which may have impacted any potential findings as related to biological changes (i.e. potentially the same effects will not be found in SG as she is a younger subject).

More recent longitudinal findings confirm that biological age-related changes are brought about through a declining f_0 , which more specifically corresponds to a declining F1 in high vowels, but not in low vowels, for which an *increase* in F1 is observed (Reubold & Harrington, 2015). In a re-analysis of the speech of Alistair Cooke, recordings were taken when he was between 42 and 95 years of age. It was found that both age-related biological effects and new dialect acquisition induced changes in the analysis: age-related changes were brought about by a declining f_0 , which in turn

influenced the F1 in his high vowels, whilst F1 increased in low vowels. The dialectal changes confirmed a shift of accent from General American towards RP in late adulthood, and it was reported that Cooke seemed to have shifted his attitude towards the American society and re-identified with his British past.

Finally, in another study by Reubold and Harrington (2017) examining the German native speech of the German female newsreader Dagmar Berghoff, recordings from the *Tagesschau* were investigated from 34-70 years of age, i.e. again over a later overall age range than that of SG. In contrast to the aforementioned studies, no consistent age-related change in F1 was observed, and *f0* stayed about the same until the age of 50 years, after which it decreased. These findings are particularly relevant to the investigation into SG, because they suggest that in German female native speech unexposed to English (as Dagmar Berghoff did not move to the US), no changes in F1 nor *f0* would be expected as a result of increasing age up to 48 years of age. However, it should be observed that Dagmar Berghoff was a trained actress and newsreader, and that she therefore most likely undertook voice training, which could have countered biological aging effects evidenced in non-trained voices. Alternatively, it is also most likely that Queen Elizabeth II, Alistair Cooke, Margaret Thatcher, and Margaret Lockwood undertook some sort of voice training, which therefore might suggest that the observed stability of F1 in Berghoff's speech may have been characteristic of *German* monolingual female speech, and therefore comparable to the speech of SG.

Bilingual longitudinal research into speech plasticity

Although a wide range of cross-sectional research has indicated phonetic and phonological attrition in a bilingual context (Bergmann et al., 2016; de Leeuw et al., 2012, 2013, 2010; de Leeuw, Tusha, & Schmid, 2017; Dmitrieva, Jongman, & Sereno, 2010; Flege, 1987; Flege & Eefting, 1987; Hopp & Schmid, 2013; Major, 1992; Mayr et al., 2012; Mennen, 2004; Ulbrich & Ordin, 2014), there is very

little *longitudinal* research into changes in native speech post adolescence, and we know very little about the trajectory of speech plasticity across the individual bilingual lifespan.

A pioneering short-term longitudinal case study revealed speech plasticity in a Brazilian-Portuguese – English late bilingual (Sancier & Fowler, 1997). The VOT values of plosives in a 27 year old female native speaker of Brazilian Portuguese was studied in three sessions: after a stay in the US right before leaving for Brazil, upon return from Brazil after a stay in Brazil, and once again, right before leaving for Brazil after a stay in the US. It was found that the VOT values of her plosives were always shorter for productions in Brazilian Portuguese than in English, but VOTs produced in both languages were shorter after the several month stay in Brazil than after the several month stay in the United States, in line with similar cross-sectional phonetic research into VOT of late consecutive bilinguals (Flege & Hillenbrand, 1984; Flege, 1987; Major, 1992). Sancier and Fowler (1997) emphasised that the perceptually guided changes in speech production occurred in a speaker who was “well past the critical period for language acquisition” (p. 421). This study was followed up by Tobin, Nam, and Fowler (2017) who obtained similar results regarding 11 Spanish-English bilinguals living in the United States. Although their results showed more extensive changes in the VOT of the bilinguals’ English than in Spanish, considerable interspeaker variation was reported with one participant evidencing changes in both languages, whilst two others showed no L1 changes at all.

Similarly, in a study by Chang (2012, 2013), 19 adult native speakers of American English (AE) learning Korean participated in a longitudinal study, which was run a total of five times over two weeks. Significant changes in L1 production were reported: the VOT of English voiceless plosives lengthened significantly from Week 1 to Week 5. In the analysis of vowel production, phonetic drift was reported to be more systematic than in the consonantal analysis, occurring uniformly over the entire vowel system (see also Mayr et al., 2012 and Guion, 2003 who suggest systematic L2 induced L1 changes, rather than counterpart-specific L2 induced L1 changes, e.g. L2 /a/ → L1 /a/). However,

in this study the acquisition of Korean was not tested, and, therefore, to a certain extent, it is difficult to know whether the participants' *acquisition of Korean* impacted the native English, or whether, potentially, their English was simply changing in Korea, but not through the acquisition of a new language (e.g. potentially as a result of exposure to Korean accented English speech).

One further case study offers insight into speech plasticity within an individual. "Freddy" spent his childhood in the Netherlands and immigrated to Indonesia at the age of 13, where he acquired Indonesian (Giesbers, 1997). Although he regularly spoke to Dutch tourists and read Dutch newspapers, it was assumed that Freddy did not have contact with the Dutch language or culture apart from his working environment. Data for the case study came from a single interview with Freddy when he was 45 years of age. As such, the study itself was not longitudinal, but the assumption was that Freddy spoke more Dutch-like while living in the Netherlands, and that, after moving to Indonesia, his Dutch was influenced by Indonesian, i.e. the possibility of Indonesian having influenced his Dutch *before* the move to Indonesia was discounted.² The authors summarised that the most frequent deviations were found on the suprasegmental level. Of a total of 48 phonological cases in their recordings, 19 observations involved incorrect word stress assignment (e.g. *óverstroming* for *overstróming* (flood)), and another 11 observations displayed an incorrect sentence intonation pattern. Other, less frequent phonological findings included consonant cluster reduction through word-final (t) deletion; and a lax vowel for a tense vowel. This study is relevant to the current study, as plasticity of both segmental and prosodic elements were investigated.

² On page 164, the following is stated: "He was born of a Javanese father and a Dutch mother. Freddy's father worked in the Dutch navy and we can assume that his proficiency in Dutch was excellent considering the fact that his own father (Freddy's grandfather) had been the headmaster of a Dutch school in colonial Indonesia. Freddy's mother is a native of the city of Heerlen in the Dutch province of Limburg". It is nonetheless possible that the father may have spoken Indonesian with Freddy during his childhood, and that this may have had some phonetic impact on his Dutch pronunciation (see e.g. Caramazza, Yeni-Komshian, Zurif, & Carbone, 1973; Sundara, Polka, & Baum, 2006 who showed bidirectional phonetic interaction in simultaneous bilinguals).

Finally, in contrast to the previous studies, 16 native Japanese children and 16 adults were investigated at two data points over a one year period of time while they acquired English in the United States (Oh et al., 2011). Their study revealed that in the adult group, no difference in Japanese vowel production occurred over time, but that the adults likewise showed no changes in L2 English vowel production across time, indicating that they had not actually acquired the English vowels. However, changes in the child group did occur, and appeared to reflect their acquisition of English vowels. The interpretation of this study suggested that there was an effect of age of acquisition (see also e.g. Ahn, Chang, DeKeyser, and Lee-Ellis (2017) and Bylund (2009), but also note the confound between attrition and acquisition in children (Schmid, 2011)). However, as already mentioned, as the Japanese adults had not actually acquired the English vowel productions, it is difficult to assert whether, had they acquired the English productions, plasticity in their native speech would have been evidenced.

Summarising, these previous longitudinal studies provide insight into how the acquisition of an L2 might impact adult native speech developments over time, but they are all restricted to shorter time spans, ranging from two to four weeks (Tobin et al., 2017), to five weeks (Chang, 2012), to eleven months (Sancier & Fowler, 1997), to one year (Oh et al., 2011). In Sancier and Fowler's longitudinal research it was ensured that the new language was acquired in the first place, which, it is argued here, would have enabled it to have had the *potential* to influence native speech production.

In the current study, SG was investigated over more than four decades, both before and after her move to the United States. As she moved to the United States midway through the recordings, it is ensured that she had acquired English, although the extent of this acquisition was not measured. Therefore, an in depth analysis into the trajectory of native speech plasticity over an individual lifespan is possible, across numerous segmental and prosodic variables.

Voiced lateral approximant /l/ in German and English

The voiced lateral approximant /l/ is known to differ in German and English. In Standard German, the back of the tongue is usually not constricted during the realisation of /l/ (Kufner, 1970; Moulton, 1970; Wells, 1982). This position of the dorsum is reflected in a higher second formant (F2) frequency and a ‘clear’ (Gimson, 1989, p. 202) or ‘light’ /l/ (Olive, Greenwood, & Coleman, 1993, pp. 204–216) lateral in German. However, the high F2 frequency of [l] in German can be influenced by either regressive or progressive coarticulation (Neppert, 1999, pp. 229, 242). Contrastingly, in AE, the back of the tongue is generally retracted during the realisation of word final laterals. The constriction creates what can be termed a velarised, or even pharyngealised, lateral which is most clearly reflected in the acoustic signal as a decrease in the frequency of the F2 (Hayward, 2000, p. 201; Kent & Read, 1996, p. 140; Olive et al., 1993, p. 207). When F2 frequency is low, the literature refers to a ‘dark’ /l/ (Gimson, 1989; Olive et al., 1993), expressed by the IPA symbol [ɫ]. Based on initial research by Sproat and Fujimura (1993), Ladefoged and Maddieson elaborate that in AE word final /l/ may be more velarised than word initial /l/, but that both are characterised by a low F2 frequency (2007). Recasens confirms the lower F2 in the North AE /l/ than in German, additionally stating that a lower F1 is observed in the lighter lateral than in the darker (2004).

Based on the characteristics of /l/ in German and English, as described above, it was predicted that under the influence of English L2 acquisition, F1 would increase over time in the speech of SG, indicating a darkening of her native German lateral. Similarly, as a result of English acquisition, F2 was predicted to decrease over time in her speech, indicating a darkening of her native German lateral. However, as previously mentioned, recent longitudinal research has indicated that with increasing age, the F1 frequency of non-low vowels in female speakers decreases, although this was not observed in a female German native speaker with little English immersion (Reubold & Harrington, 2015, 2017; Reubold et al., 2010).

High front unrounded /i/ in German and English

Very generally, the high vowels in German are considered to be higher than those in English. For example, Delattre has stated that English “close vowels are less close [than German close vowels]” (Delattre, 1964, p. 53, as cited in Biersack, 2002, p. 62). Such articulatory descriptions are in line with a lower F1 frequency in the German high front unrounded /i/ vowel, in comparison to the English /i/. In line with these impressionistic descriptions, an acoustic study of /i/ found an average F1 frequency of 437 Hz and an average F2 frequency of 2761 Hz for AE females (Hillenbrand, Getty, Clark, & Wheeler, 1995, p. 3103). Another study reported an average F1 frequency for AE women of 390 Hz and an average F2 frequency of 2826 Hz (Yang, 1996). In contrast, German females have been reported to have an average F1 frequency of 302 Hz, and an average F2 frequency of 2369 Hz (Künzel, 2001), and of respectively 302 Hz and 2533 Hz (Sendlmeier & Seebode, 2006). Accordingly, it could be generalised that German /i/ is both slightly closer than the AE /i/, and also potentially that German /i/ is slightly more back on the horizontal axis of the vowel space, due to the reported lower F2 frequency in German /i/ than in English.

Based on the characteristics of /i/ in German and English, as described above, it was predicted that under the influence of English L2 acquisition, F1 would increase over time in the speech of SG, indicating a more open pronunciation of her native German high front unrounded /i/ vowel. Similarly, as a result of English acquisition, F2 was predicted to increase over time in her speech, indicating a more front pronunciation of her native German /i/. On the other hand, as SG aged at the same time as acquiring more English, it was considered possible that F1 in her native German speech would become lower over time given previous findings regarding effects of aging on speech, although, again, the lowering effect of F1 in high vowels was not observed in a female German native speaker with little English immersion (Reubold & Harrington, 2015, 2017; Reubold et al., 2010).

Low front unrounded /a/ in German and English

Very generally, it has been considered that the German centre of gravity is higher than that of English, i.e. “[English] centre of gravity is lower. And its low vowels are more extreme (close to cardinal vowels) than its high vowels, which is not the case with [German]” (Delattre, 1964, p. 53, as cited in Biersack, 2002, p. 62). In the past, there have been thought to be two low unrounded vowels in both German and in English (Delattre, 1964). Traditionally, these were transcribed as /a/ and /ɑ/ in German, with the former being a low front unrounded vowel and the latter being a low back unrounded vowel; in English, similar corresponding vowels have been transcribed as /æ/ and /ɑ/ with the former considered to be more front than the latter (Delattre, 1964). However, more recently, as described, /a/ has been used to transcribe these vowels in both German and English. In early acoustic analyses comparing German and English, research revealed that F1 frequency values for all of these vowels were the same (i.e. 750 Hz); however, F2 values were reported to differ between /a/ in German and /æ/ in English, respectively 1250 Hz in German /a/ and 1700 Hz in English /æ/ (Delattre, 1964). A recent acoustic investigation indicates that in AE female speakers, the average F1 value for /æ/ is 669 Hz, and the average F2 value is 2349 Hz (Hillenbrand et al., 1995). Similarly examining AE female speakers, Yang (1996) reported average F1 and F2 values of respectively 825 Hz and 2059 Hz. A formant analysis of Standard German female speakers arrived at the values in /a/ of 710 Hz for F1 and 1505 Hz for F2; and in /a:/ of 781 Hz for F1 and 1462 Hz for F2 (Künzel, 2001). Similarly examining Standard German female speakers, Sendlmeier and Seebode (2006) arrived at the average frequency values in /a/ of 836 Hz for F1 and 1586 Hz for F2; and in /a:/ of 896 Hz for F1 and 1517 Hz for F2. Although the latter studies into German separated long and short vowels, in comparing the AE female speakers with the Standard German female speakers, one can deduce that /a/ in German appears to be more back than its English equivalent, as reflected by lower F2 values in German than in English. However, with regard to closeness of /a/, the acoustic findings

are less clear, although analyses would suggest that /a/ is more open in English than in German, as reflected by higher F1 values in English than in German.

Given these characteristics of /a/ in German and English, as described above, it was predicted that as a result of English L2 acquisition, F1 would increase over time in the speech of SG, indicating a more open pronunciation of her native German low front /a/ vowel. Similarly, as a result of English acquisition, F2 would increase over time in her speech, indicating a more front pronunciation of her native German /a/. However, the predicted *increase* of F1 frequency in her native German speech, due to English L2 acquisition, was thought to potentially be amplified due to the age effect of open vowels exhibiting a potential *increase* in F1 frequency as a function of biological aging although, again, the lowering effect of F1 in high vowels was not observed in a female German native speaker with little English immersion (Reubold & Harrington, 2015, 2017; Reubold et al., 2010).

Pitch in German and English

Impressionistically, English female voices have been reported to be high-pitched and “sound aggressive and over-excited to the German hearer” (Gibbon, 1998, p. 89). Instrumental cross-sectional research which has contrasted pitch in German and English indicates that German females have a lower pitch level and a narrower pitch span than English females of the same age group (Mennen et al., 2014, 2012; Mennen, Schaeffler, & Docherty, 2007; Scharff-Rethfeldt et al., 2008) although the English L2 may also influence the German L1 (de Leeuw, 2009, 2019).

Therefore, in this stage of the current analysis, pitch level and span were investigated in order to examine whether pitch level would increase and pitch span would widen under the continued influence of English over SG’s lifespan. Given the above differences between German and English pitch, it was predicted that as a result of English L2 acquisition, mean f0 would increase over time in the native German speech of SG, indicating an increasing pitch level over time. Similarly, as a result

of English acquisition, 80%Range was predicted to increase over time in her native German speech, indicating a widening of pitch span over time. Finally, due to English acquisition, maxf0 was predicted to increase over time in the native German speech of SG, indicating wider maximum pitch excursions.

As a function of biological age, it was nonetheless thought possible that f_0 would decrease over time (see e.g. Linville, 1996; Linville & Rens, 2001; Reubold & Harrington, 2015, 2017), which could have a narrowing effect on 80%Range and decreasing effect on maxf0, although again, this lowering effect on f_0 was not observed in a female German native speaker with little English immersion (Reubold & Harrington, 2015, 2017; Reubold et al., 2010).

Objectives of the study

The main objective of the present research was to expose the trajectory of plasticity in the spontaneous native German speech of SG from youth to mid adulthood in the segmental and prosodic variables described above. This objective was set to pursue the questions of whether and how native speech remains plastic post adolescence within the context of late bilingualism and therefore expands on the aforementioned monolingual and bilingual longitudinal research by delving into similar questions within a late bilingual over an extended period of time. It has been suggested that the first years after migration have the greatest influence on the extent to which an individual undergoes attrition (de Bot & Clyne, 1994); however, as SG moved to the United States already fluent in English, the first years after moving may have been less impactful. With regular contact to English before her move, and to German after her move, as will be discussed, plasticity effects across the four decades might be more variable, with ups and downs dependent also on recent language exposure (Sancier & Fowler, 1997). That said, to date no longitudinal study has verified such claims, and the primary objective of the current study was therefore to investigate plasticity in SG's native German spontaneous speech as a result of the acquisition of L2 English.

A secondary objective of this study was to investigate whether plasticity in the native speech of a late bilingual, if evidenced at all, does so uniformly across all variables examined, or whether certain variables are more likely to undergo change than others. It has been suggested that cross-linguistic interactions operate at a system-wide level (Mayr et al., 2012), rather than at the level of individual sounds, which is consistent with related research into early bilinguals (Guion, 2003) short-term phonetic drift effects (Chang, 2012; Guion, 2003), as well as with the notion of language specific phonetic settings (Laver, 1980; Mennen, Scobbie, de Leeuw, Schaeffler, & Schaeffler, 2010). The idea of a systematic L1 change is to a certain extent unsupported by models of L2 acquisition, such as the SLM (Flege, 1995) which maintains that perceptual similarity between *individual* sounds underlies L2 speech perception, and therefore also potential merging between L1 and L2 counterparts, e.g. if L1 /a/ and L2 /a/ are perceived as similar, although they are different, these counterparts will merge in production as well. Likewise, perceptual similarity between individual properties of the L1 and the L2 underlies related models of speech perception and production (Best, 1995; Escudero, 2005). Moreover, dissimilation effects, which have also been reported in phonetic attrition studies (de Leeuw et al., 2012; Evans & Iverson, 2007; Flege & Eefting, 1987), do not feed into the interpretation of systematic change cleanly. If there were a system wide shift, it is unclear why and how some individuals evidence dissimilation whilst others evidence assimilation *for the same phonetic variable*. For example, in de Leeuw et al. (2017), three of the Albanian-English bilinguals evidenced dissimilation of coda-/l/, whilst three evidenced assimilation. If a system-wide change was occurring in the bilinguals' speech, it would be more intuitive to assume that coda-/l/ would *move in the same direction* for all of the speakers. As this did not occur, it suggests that other factors – aside from systematic changes, i.e. L2 system to L1 system - most likely also play a role in determining L2 influence on the L1 (such as socio-indexical information). Through examination of numerous segments, particularly focussing on formant values, it will be possible to determine whether e.g. the vowels follow a general trend towards more open

(higher F1) realisations as in Mayr et al., 2012, which examined the effect of English late L2 acquisition on Dutch native speech, or whether differences are observed between variables over time.

A final objective of this study was to investigate the potential effects of biological aging on the speech of SG in a late bilingual context. As previously discussed, some research has shown that aging effects cause a decrease in female f_0 over time, a decrease in the F1 of high vowels, and an increase in the F1 of low vowels (Linville, 1996; Linville & Rens, 2001; Reubold & Harrington, 2015, 2017; Reubold, Harrington, & Kleber, 2010). However, it has also been shown in the German female speaker Dagmar Berghoff, who had no documented increased English exposure, that there were no noticeable changes in F1 of her high vowels, and no rising trend in F1 of low vowels. Moreover, f_0 only started to drop at 50 years of age, which could suggest that no decrease in f_0 would be expected in the recordings of SG, and that there would be no F1 changes as a result of biological aging. However, the findings from Berghoff run counter to the previous case studies investigated by Reubold et al., and it may be that she therefore represents a highly trained anomaly.

Based on these three objectives, the following general hypothesis was established.

The production of German native speech patterns, as measured in segmental and prosodic variables, will change over time, as they are influenced by increased exposure to English counterparts.

Systematic changes regarding variation between variables were considered important to bear in mind, as well as any biological aging effects which may have overridden or enhanced L2 effects.

Methodology

Stefanie Graf

The subject of this case study is Stefanie Graf (SG), born 14 June, 1969 in Mannheim, Germany, and raised in a monolingual German environment in Brühl, Germany. SG is the world's longest number 1

ranked tennis player and is widely recognised as the world's greatest tennis player (see both Women's Tennis Association and the Association for Tennis Professionals)³.

During her childhood, she was coached by her German father until 1986 (Finn, 1991; Ostler, 1987). At 17 years of age, a new Czech coach, Pavel Slozil, was hired to supplement her father's coaching, at which point her exposure to English increased as she travelled more frequently on the international tennis circuit. At 30 years of age, in part due to injuries, SG retired from her tennis career and was fully immersed in English upon moving to Las Vegas, USA in 2000 to be with her husband, Andre Agassi (Danis, 1999). However, SG will have started to acquire English before she moved to Las Vegas; she will have learned English at school in Germany, and have used English frequently in an international environment as a professional tennis player, both in Germany and abroad, and her age of English acquisition (AOA) is therefore earlier than the onset of her move to Las Vegas.

Since moving to Las Vegas, SG has reported a decrease in the amount of German she uses. For example, in 2009 (40 years of age) she stated that she could not really ever lose touch with German.

In unserer Familie in Las Vegas unterhalten wir uns überwiegend auf Englisch. Aber ich spreche mit meinen Kindern auch Deutsch, und sie verstehen es gut. Außerdem bin ich ständig mit meinem Büro in Deutschland oder mit meiner Stiftung in Verbindung. So richtig rauskommen kann ich also gar nicht.

In our family in Las Vegas, we mostly speak English. But I also speak German with my children, and they understand it well. Otherwise, I'm frequently in contact with my office in Germany, or in contact with my charity. So I can't really ever lose touch. (Herffs, 2009)

³ See [www.wtatennis.com] and [www.atpworldtour.com].

However, later in 2012 (43 years of age), she is reported to have stated that she sometimes has difficulties finding the right words in German.

Ja, wenn ich mit ihnen allein bin [spreche ich mit den Kindern Deutsch]. Wenn ich aber will, dass sie etwas auf jeden Fall verstehen, spreche ich Englisch mit ihnen. Außerdem unterhält sich auch meine Mutter mit ihnen auf Deutsch. Ich habe aber mittlerweile manchmal Schwierigkeiten, die richtigen Worte auf Deutsch zu finden.

Yes, when I'm alone with the children, [I speak German with them]. But when I want to make sure that they definitely understand something, I speak English with them. My mother also speaks German with them. But lately I've sometimes had difficulties finding the right words in German. (Hüdaverdi & Mitatselis, 2012)

However, although living in Las Vegas full time, SG has continued to maintain a strong connection to Germany, and she has reported that she returns five or six times annually for personal and professional reasons related to her charity Children for Tomorrow and distinguishes between the German terms “zu Hause” (Eng. at home) and “Heimat” (Eng. homeland) (2013, 44 years old).

Dadurch, dass meine Kinder in die Schule gehen, [komme ich] etwas seltener [nach Deutschland] [...]... Etwa fünf-, sechsmal im Jahr. Im Sommer, während der Schulferien, versuchen wir immer etwas länger zu bleiben... Heimat wird immer Deutschland bleiben. Zu Hause aber ist dort, wo meine Familie ist.

As my children go to school, I come less frequently to Germany [...] Around five or six times per year. In the summer during the school holiday, we always

try to stay longer... The homeland will always be Germany. But I'm at home where my family is. (Hungermann, 2013)

More recently, in 2016 (47 years of age), she is reported to have stated that she rarely speaks German.

Ich spreche [Deutsch] mittlerweile eigentlich nur noch, wenn mir irgendwas nicht passt. Dann rutscht mir "Mensch, jetzt mach mal!" raus und [die Kinder] wissen: Jetzt müssen sie wirklich aufpassen.

I actually only ever speak German now when I'm upset. Then "*Mensch, jetzt mach mal!*" (Eng. C'mon, hurry up!) slips out and the children know – now they really have to be careful. (Mol-Wolf & Voss, 2016)

Although SG has had an exceptional career as a tennis player, her descriptions of her language use patterns as a late bilingual can be interpreted as representative of many other late bilinguals who have immigrated to a new country in adulthood. Given the geographical distance between Germany and the United States, she may be able to return more regularly than others who have emigrated from Europe to North America (see e.g. Schmid, 2004 and de Leeuw et al., 2010, in the latter, late bilinguals return on average less than once per year to Germany from Canada), but many late bilinguals might also have family and friends who visit them regularly, or live in closer proximity to their home countries, thereby enabling them to return more frequently. In some ways her language exposure, which was characterised by regular exposure to English before moving to Las Vegas, as well as continued frequent contact with German post move to Las Vegas, is perhaps more representative of bilingual immigrants of present, in a connected world, where international travel can be considered less costly and faster than before the turn of the 21st Century. Nevertheless, by very nature of the move, such late bilinguals, like SG, who have established themselves in a new country, are likely to speak their new language far more regularly than their native language, and most definitely more likely than they did in their country

of origin. The findings from the phonetic analysis of SG's native speech are therefore interpreted as applicable to other late bilinguals who have immigrated to a new country in adulthood, although due to the fact that this case study is based on only one speaker, it is considered possible that some of the findings may in part be due to unique characteristics and developments in the speech of SG.

Recordings

Recordings of SG were collected from various online German media resources, such as *ZDF* and *RTL Mediathek*. The recordings were conducted in various settings, for example after SG won a match on the tennis court, in an interview room in either Germany or abroad, or at her charity in Hamburg. Initially, 40 recordings were selected. From this total, 36 recordings of SG were finally examined, ranging in duration from approximately 1-20 minutes. Four recordings were discarded because there was too much background noise in them, e.g. people were cheering, or the recording was overlaid with music. In total, 1250 segments were analysed in all 36 recordings, with an average of 38 segments per recording (in total 491 /l/ segments, 261 /i/ segments and 175 /a/ segments). For the prosodic analysis, one value for each variable was obtained per recording as these were long term durational measurements over the entire recording.

The recordings were transcribed by hand using Praat (Boersma & Weenink, 2010) initially at the sentence level orthographically. Thereafter words containing the relevant segmental variables were located and the variables were transcribed using IPA including the segments on either side of the targeted segments. The advantage of hand transcriptions in this case was that all recordings were listened to by the author in detail, such that a provisional impressionistic analysis was also able to be conducted, as the content of the interviews was also considered informative. Once the recordings had been annotated, relevant phonetic variables were measured, as detailed below.

The original sampling frequency of the recordings varied, as in the previous longitudinal studies into monolinguals (Harrington, 2006; Reubold & Harrington, 2017; Reubold et al., 2010)

from 16 kHz to 22 kHz to 24 kHz, largely due to technological developments over time. Through the downloading process, recordings were resampled uniformly to 44.1kHz.

As already mentioned, recordings were all of spontaneous speech, and therefore comprise false-starts, hesitation markers, long pauses, and interviewer questions which were rejected by SG, due to their inappropriate or personal nature. The overall impression from the recordings is that her speech was informal, and therefore representative of naturalistic communicative events experienced by both monolinguals and bilinguals who, in their day to day lives, encounter different people from varying backgrounds, with different communicative agendas. For this reason, the analysis of these recordings is considered to enhance previous studies implementing controlled word list elicitation methods (see e.g. de Leeuw, Mennen, & Scobbie, 2012, 2013; de Leeuw, Tusha, & Schmid, 2017; Mayr, Price, & Mennen, 2012) and read speech (see e.g. Harrington, 2006; Reubold et al., 2010).

Furthermore, as a public figure, SG was interviewed and recorded without the primary objective of language testing, but rather to gather information regarding her tennis performances, visits to Germany, family life in Las Vegas, or regarding her career. Accordingly, the methodological constraint which can potentially arise in longitudinal linguistic studies of bilinguals, that the repeated testing of variables within the bilingual group may disturb the “natural course of the process [the test] hoped to track down” (Jaspaert & Kroon, 1989, p. 81), is considered to have been circumvented in the current research, because no “test” as such was consistently implemented during these recordings which would have potentially maintained her L1.

Segmental analysis

The primary aim of the segmental analysis was to examine the trajectory of native speech segments in the spontaneous German speech of SG, and to see whether these segments might evidence different trajectories under the influence of English L2 acquisition. To do so, specified formant frequencies were examined which are known to differ between English and German, as described

previously. Formant frequencies were measured in the lateral approximant /l/ (F1 and F2); the rhotic /r/ (F3); the high front vowel /i/ (F1 and F2); the low front vowel /a/ (F1 and F2); and the high back vowel /u/ (F1 and F2). However, only the following sounds exhibited significant changes and therefore, due to limitations in space, only the following segments were analysed in more detail.

- voiced lateral approximant /l/
- high front unrounded /i/
- low front unrounded /a/

Measuring formants

Formant frequencies were measured in Praat (Boersma & Weenink, 2010) with standard settings. The window length was set to 25ms; five formants were displayed in the spectrogram with the maximum formant frequency of 5500Hz; and a pre-emphasis of 50Hz. In Praat, Burg's algorithm (Andersen, 1974) is used to extract formant frequencies from the speech signal through linear predictive coding. As in Harrington et al. (2010), formants were sometimes inspected using a narrowband (50 Hz) as well as wideband displays, especially when F1 and F2 were very close together.

All segments (i.e. /l/, /i/ and /a/), measured at the mid-point, were delineated manually (Moosmüller, Schmid, & Kasess, 2015), initially through listening to the recordings and observing where the segments occurred. Segments were not included if their duration was so short that no reliable measurement could be taken (Harrington, Palethorpe, & Watson, 2007). Changes in the waveform and spectrogram's intensity as well as formant transitions were used as the main determiners of segmental boundaries (Chang, 2012; Mayr et al., 2012; Moosmüller et al., 2015). Onset of /l/, /i/, and /a/ was marked at the first glottal striation where the formants were visible, while offset was marked either at the final glottal striation or at the point where a clear F1 and F2 were no

longer visible. F1 and F2 were then measured at the mid-point of the segment, as in e.g. Harrington, 2006; Reubold et al., 2010, in order to minimise coarticulation effects.

Prosodic analysis

The primary aim of the prosodic analysis was to examine whether the acquisition of English pitch patterns would affect native speech pitch patterns in SG. A number of prosodic variables were extracted from the pitch contour in the speech of SG: mean f_0 (pitch level), *80%Range* (pitch span), and *maxf₀*, as described below.

Measuring pitch

For this stage in the analysis, recordings were visually and auditorily inspected in Praat before running a script to extract the pitch variables. For the inspection, the waveform and spectrogram were initially examined in 5-10 second intervals, and where the pitch contour was viewed to “jump up and down, doubling or halving the actual f_0 ” (Styler, 2013, p. 15), the audio files were examined in more detail. In doing so, sections of approximately 1000ms were further visually and auditorily inspected in order to gauge whether the pitch contour indeed reported an accurate f_0 . In some cases, the individual cycles of the waveform were also examined and measured to compare the manual pitch measurement with the pitch contour. Following the guidelines below, where the pitch contour in Praat was considered to be unreliable, these portions were deleted, as they would have otherwise adversely affected the overall f_0 measurements (Styler, 2013, p. 17).

1. Where creaky voice occurred, the pitch contour in Praat was considered to be unreliable because although auditorily a low pitch was heard, and verified by a visual single cycle inspection of the waveform, the pitch contour in Praat often reported a high f_0 , or sometimes even dropped out altogether (see also Styler, 2013).

2. Similarly, at some points in the analysis, where *no* speech was actually produced, the pitch contour was nevertheless reported in Praat. In these cases, the portion of silence was also deleted from the original recording, as, again, an inaccurate *f0* was reported in Praat.

Analysis settings were those recommended for women: pitch floor was set to 100 Hz while pitch ceiling was set to 500 Hz. Thereafter, a number of different values were obtained. For pitch level, mean *f0* (Hz) (Mennen, Schaeffler, & Docherty, 2007) was extracted, in order to examine whether over time the pitch of SG would increase under the influence of English, or decrease as a function of biological age. Maximum pitch excursions have also been shown to socially index speakers in conversation (Podesva, 2007); as such, maximum *f0* (*maxf0*) was also extracted to investigate whether - although mean *f0* might have decreased with time - an increase in maximum *f0* excursions might have occurred. Finally, for pitch span, the difference between the 90th and 10th percentile range (*80%Range*) in semitones (ST) was obtained.

Statistical analysis

For both the segmental and prosodic results, data were organised in CSV files using Excel software. Thereafter, R software (R Core Team, 2017) was used for the analyses and a series of linear mixed-effects regression models were built using the lme4 package (Bates, Maechler, Bolker, & Walker, 2015). The fixed effect was always 1. age of SG (continuous variable from 12 to 48 years of age) and for /l/, but not /i/ and /a/, 2. position in syllable (three levels: onset, nucleus and coda); whilst random effects were type of word (e.g. verb, noun, preposition), preceding sound, and following sound. The choice of age of SG as the fixed factor was based on the general hypothesis of the study, as in e.g. Harrington et al. (2010). The choice of position in syllable was motivated by the observation that the light lateral occurs more frequently in onset and the dark lateral more frequently in coda position in AE (Ladefoged & Maddieson, 2007; Sproat & Fujimura, 1993), whilst the vowels were always in nucleus position. For the latter random factors, no specific predictions were made with regard to how

they would influence the dependent variable, as e.g. the specific sound represented the preceding and following sound, not a categorical distinction such as front versus back. Using the lmerTest function in R (Kuznetsova, Bruun, Brockhof, & Haubo Bojesen Christensen, 2017) with both the summary and step functions (which performs automatic backward model selection of fixed and random parts of the linear mixed model), linear mixed models were fit by REML t-tests using Satterthwaite approximations to degrees of freedom. An alpha level of 0.05 was used throughout for hypothesis testing (model outputs are displayed in Table 2).

Results

Long-term changes in segmental variables

The first linear mixed model regression was conducted with F1 frequency of /l/ as the dependent variable to see if, as predicted, there would be an increase in F1 over time. Only the fixed factor of age had a significant influence on F1, i.e. $\chi^2[1] = 33.6804, p < .0001$, whereas position in syllable did not. As displayed in Figure 1, F1 frequency decreased over time in contrast to the L2 acquisition prediction. Of the random factors, both preceding and following sound had a significant influence on F1, i.e. respectively $\chi^2[1] = 16.23, p < .0001$ and $\chi^2[1] = 21.21, p < .0001$, whereas type of word did not. In the second regression, the dependent variable was F2 frequency, in order to see whether there was a significant darkening of /l/ over time as a result of English L2 acquisition. Again, only the fixed factor of age had a significant influence on F2, i.e. $\chi^2[1] = 10.522, p < .01$. As shown in Figure 1, with increasing age, and therefore increasing exposure to English, F2 decreased, i.e. the lateral became darker over time. Note additionally that the amount of laterals in onset position increased after her move to Las Vegas from 53% of total lateral tokens pre-move to 69% post-move, thus revealing that even though laterals in onset position became more frequent, there was still a significant decline in F2 frequency. Of the random factors, both preceding and following sound had a significant influence on F2, i.e. respectively $\chi^2[1] = 43.50, p < .0001$ and $\chi^2[1] = 62.81, p < .0001$.

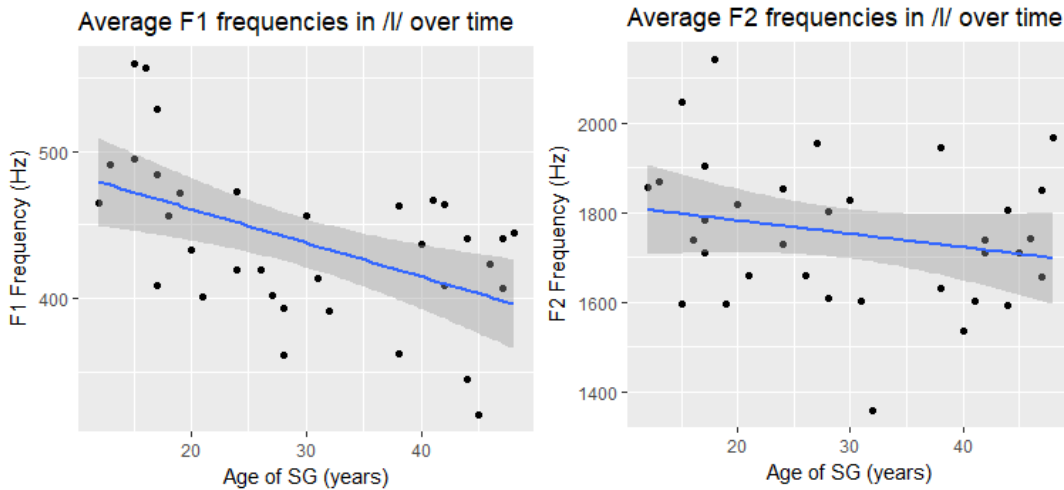


Figure 1: Average F1 and F2 frequencies in /i/ of native speech of SG, displaying significant decreases over time, interpreted to reflect the effects of biological aging, 95% CI.

For the analysis of /i/, the dependent variable was F1 frequency, in order to see whether an increase would occur. As /i/ was only ever in nucleus position, the fixed effect was only age of SG. The fixed factor of age had a significant influence on F1, $\chi^2[1] = 13.283$, $p < .0001$, with a decrease in overall F1 frequency revealed, in contrast to the prediction as a result of L2 acquisition (see Figure 2), most likely as a result of natural aging effects. Of the random factors, only following sound had a significant influence on F1 $\chi^2[1] = 26.27$, $p < .0001$. In the second analysis of /i/, the dependent variable was this segment's F2 frequency, in order to see whether it would increase over time. As expected, the fixed factor of age had a significant influence on F2, i.e. $\chi^2[1] = 24.0217$, $p < .0001$, with, as predicted, an overall increase in F2 frequency (see Figure 2). Here, the random effects of preceding sound and type of word were significant factors, respectively $\chi^2[1] = 4.92$, $p < .05$ and $\chi^2[1] = 5.20$, $p < .05$.

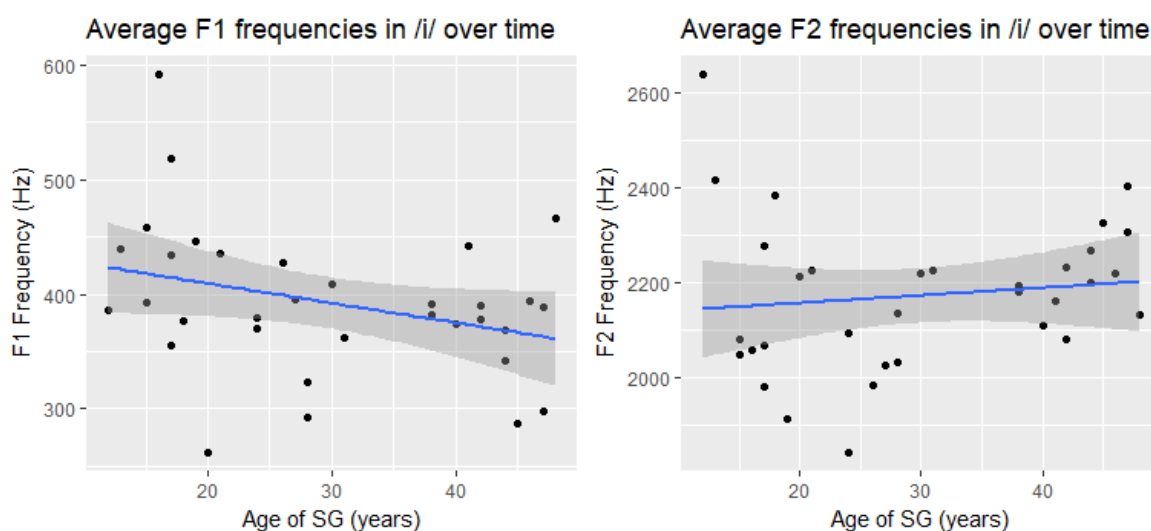


Figure 2: Average F1 and F2 frequencies in /i/ of native speech of SG, displaying a significant decrease in F1 over time and a significant increase in F2. 95% CI.

In the next analysis of /a/, the dependent variable was F1 frequency, in order to see whether it would increase as a result of English L2 acquisition with the fixed effect of age of SG and random effects of type of word, preceding sound, and following sound. Only the fixed factor of age had a significant influence on F1, i.e. $\chi^2[1] = 10.7448, p < .01$, with, as predicted, an increase in overall F1 frequency revealed (see Figure 3), potentially augmented by natural aging effects. Of the random factors, again, only following sound had a significant influence on F1 $\chi^2[1] = 4.53, p < .05$. In the second analysis of /a/, the dependent variable was F2 to see whether it would potentially increase, as predicted as a result of English L2 acquisition. The same fixed and random effects were used as in the previous step of the /a/ analysis; however, this test was not significant.

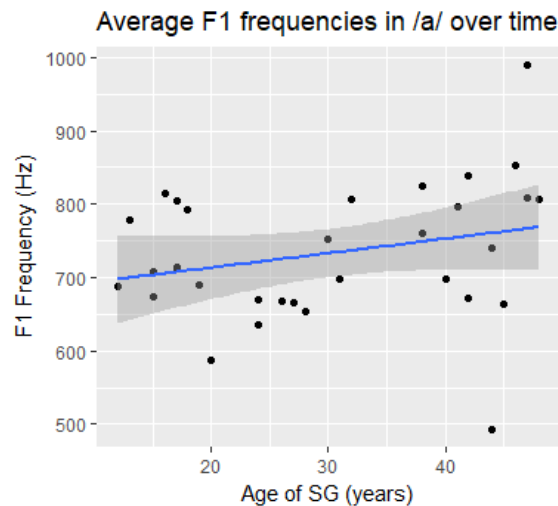


Figure 3: Average F1 frequencies in /a/ of native speech of SG, displaying a significant increase in F2 frequency over time, interpreted to reflect the effects of English L2 acquisition, although potentially augmented by natural aging effects, 95% CI.

The segmental findings are summarised in Figure 4 which shows ellipses of /l/, /i/ and /a/, drawn in ggplot (Hadley, 2016) with the default confidence level of .95, i.e. 95% of the spontaneous speech tokens of SG fell within the radius of these segments. In addition to the changes in F1 and F2 mentioned above, the ellipses also show a high level of variation in the segmental speech production of SG both before and after her move to Las Vegas, as also reported in Table 1.

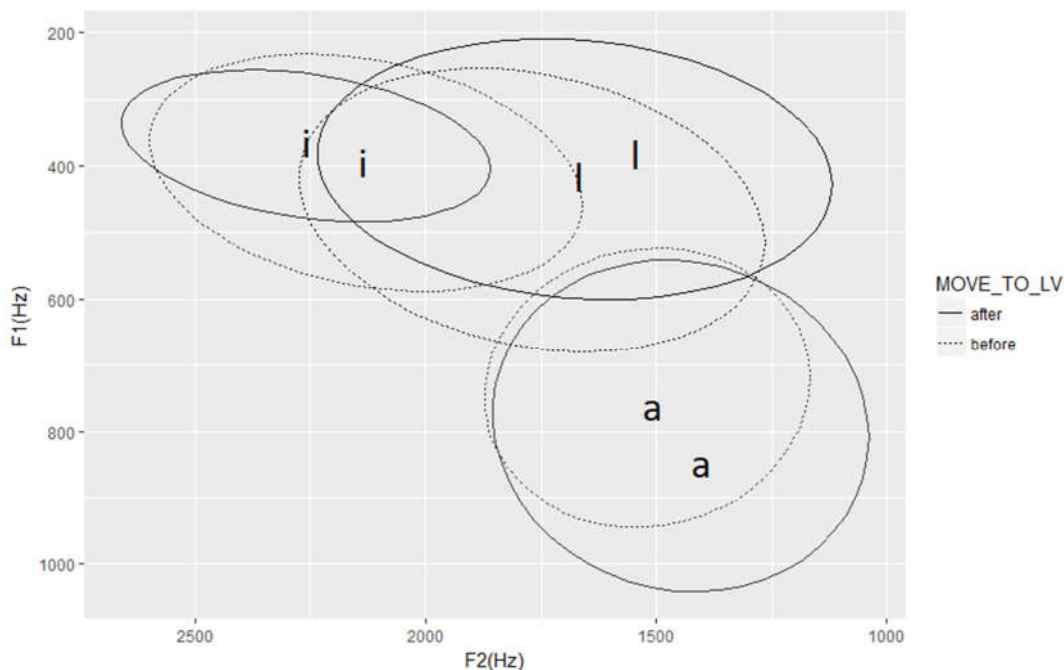


Figure 4: Ellipses of /l/, /i/ and /a/ before and after SG's move to Las Vegas.

Results /l/				
	<i>F1 before move</i>	<i>F1 after move</i>	<i>F2 before move</i>	<i>F2 after move</i>
<i>mean</i>	468.1	414.2	1776.8	1669.9
<i>stdev</i>	94.9	98.7	238.6	258.2
<i>n</i>	174	279	178	287
Results /i/				
	<i>F1 before move</i>	<i>F1 after move</i>	<i>F2 before move</i>	<i>F2 after move</i>
<i>mean</i>	413.3	371.02	2117.5	2261.5
<i>stdev</i>	88.4	61.2	213.0	208.9
<i>n</i>	86	169	86	169
Results /a/				
	<i>F1 before move</i>	<i>F1 after move</i>	<i>F2 before move</i>	<i>F2 after move</i>
<i>mean</i>	723.2	779.4	1530.5	1485.1
<i>stdev</i>	102.1	127.3	174.4	250.7
<i>n</i>	80	92	80	92

Table 1: Means, standard deviations and number of tokens of F1 and F2 (Hz) of /l/, /i/ and /a/ before and after SG's move to Las Vegas.

	<i>Estimate</i>	<i>Std. Error</i>	<i>t-value</i>	<i>p-value</i>
<i>F1 of /l/</i>				
(Intercept)	525.7500	19.4181	27.075	< 2e-16 ***
Age of SG	-2.1131	0.3713	-5.691	2.32e-08 ***
Position in word, onset	-28.9442	18.4061	-1.573	0.124
<i>F2 of /l/</i>				
(Intercept)	1800.6949	59.4662	30.281	< 2e-16 ***
Age of SG	-2.9943	0.9604	-3.118	0.00194 **
Position in word, onset	-107.0731	60.0187	-1.784	0.08146
<i>F1 of /i/</i>				
(Intercept)	426.6912	19.7134	21.645	< 2e-16 ***
Age of SG	-1.4039	0.3817	-3.678	0.000289 ***
<i>F2 of /i/</i>				
(Intercept)	2025.887	56.203	36.046	< 2e-16 ***
Age of SG	5.681	1.178	4.823	2.46e-06 ***
<i>F1 of /a/</i>				
(Intercept)	685.1481	27.1978	25.191	< 2e-16 ***
Age of SG	2.3907	0.7371	3.244	0.00147 **

Table 2: Estimates, standard errors, t values and p values for each linear mixed effect model, significance codes: * < 0.001; ** < 0.01, * < 0.05.**

Long-term changes in prosodic variables

In the prosodic analysis, only one measurement was obtained for mean f_0 , 80%Range and $maxf_0$ per recording (i.e. three measurements per recording), and, therefore, no random effects were measured. Accordingly, a single linear regression was conducted with age of SG as the dependent variable and mean f_0 , $maxf_0$, and 80%Range as independent variables. This model proved to be significant ($F(3,31)=9.148$, $p<.0001$) with a total adjusted R^2 of .418. Only mean f_0 added significantly to the model, $p<.0001$ with a standardized beta value of -.609. The Pearson's correlation test indicated a significant negative relationship between mean f_0 and age of SG ($r=-.645$, $p<.0001$), indicating that as SG became older, her pitch decreased, as expected as a result of natural aging effects. Moreover, a Pearson's correlation for 80%Range and age of SG was also significant ($r=-.315$, $p<.05$), indicating that with increasing age, her pitch span decreased. Surprisingly, although her overall pitch decreased

with time, her $maxf_0$ significantly increased with age ($r=.287, p<.05$). This difference also proved to be significant in a dependent t-test comparing $maxf_0$ before her move to Las Vegas with after her move ($t(16) = -2.218, p<.05, r=.49$), revealing a large effect size (Figure 5), although both before and after her move to Las Vegas there was a high level of variation in $maxf_0$ (see Table 2).

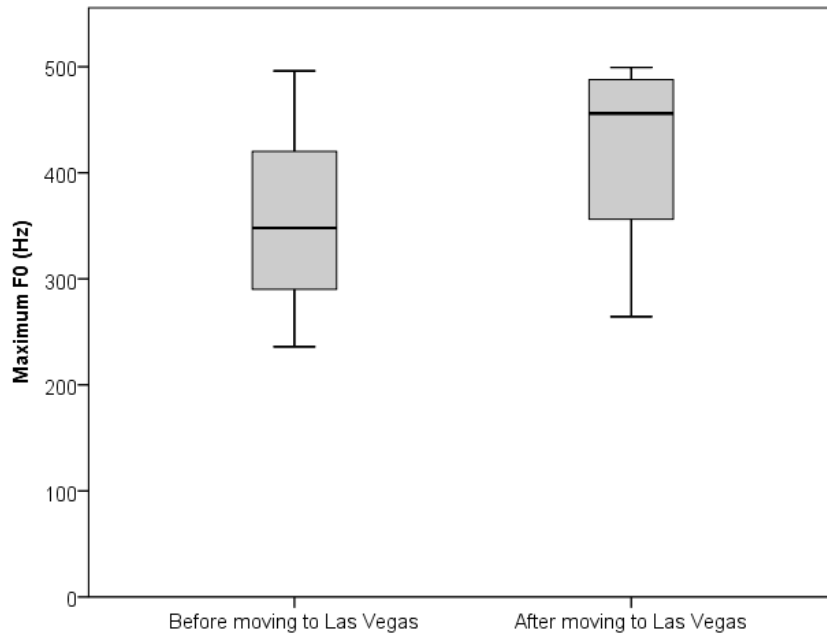


Figure 5: Boxplot indicating significantly higher maximum f_0 (Hz) in the speech of SG after moving to Las Vegas in comparison to before.

Results mean f0 (Hz)		
	<i>Before move to Las Vegas</i>	<i>After move to Las Vegas</i>
<i>mean</i>	218.6	197.5
<i>stdev</i>	18.9	9.1
Results 80%Range (ST)		
	<i>Before move to Las Vegas</i>	<i>After move to Las Vegas</i>
<i>mean</i>	5.0	3.9
<i>stdev</i>	3.7	1.0
Results maxf0 (Hz)		
	<i>Before move to Las Vegas</i>	<i>After move to Las Vegas</i>
<i>mean</i>	358.2	418.6
<i>stdev</i>	82.1	81.5

Table 3: Means and standard deviations of F1 and F2 (Hz) of f_0 , 80%Range and max f_0 before and after SG's move to Las Vegas

Discussion

The primary objective of the present research was to expose the trajectory of plasticity in the spontaneous native German speech of SG from youth to mid adulthood as a consequence of English L2 acquisition. As hypothesised, modifications to L1 segmental and prosodic variables occurred over time, most likely having been influenced by increased exposure to English counterparts. With regard to the front – back dimension of /l/, /i/ and /a/, results showed a significant lowering of the second formant (F2) frequency in /l/, possibly suggesting an overall darkening of the German lateral under the influence of English as a second language (L2), as well as a significant increase in the F2 frequency of /i/, indicating a more front pronunciation, as predicted due to English L2 acquisition (see Figure 4). Through an analysis of spontaneous speech, these findings corroborate previous cross-sectional research into attritional effects in the lateral of German native speakers who have acquired North AE (Bergmann et al., 2016; de Leeuw et al., 2013, 2017). However, no changes were observed in the F2 frequency of /a/, which substantiates previous cross-sectional findings into phonetic attrition in this same sound (Bergmann et al., 2016), and it is also important to note that in the preliminary analysis of the data, no significant changes occurred in the F1 and F2 frequencies of /u/ nor in the F3 frequency of /r/. More generally, these segmental findings support previous short-term longitudinal research into changes in native speech as a result of the acquisition of a new language in adulthood (Chang, 2012; Sancier & Fowler, 1997), although the current findings do so over a much longer time span of 40 years.

With regard to the prosodic level of analysis, the average *maxf0* in all recordings increased significantly with age, as predicted as a result of English L2 acquisition. This finding enhances previous research which suggests that in phonetic studies examining change in the L1 as a result of L2 acquisition, “the most frequent deviations are found on the suprasegmental level” (Giesbers, 1997, p. 166), as in the current investigation only one of the three prosodic hypotheses was upheld,

whilst biological aging effects also influenced the native speech of SG over time, as will be discussed shortly. The prosodic results also support previous cross-sectional studies into attrition of prosodic elements of native speech which indicate that L2 English prosody affects L1 German prosody (de Leeuw, 2019; de Leeuw et al., 2012; Mennen, 2004).

It is important to note that both before and after SG's move to Las Vegas, there was a wide range of variation in her spontaneous speech production with regard to both the segmental and prosodic variables (see Table 1 and Table 2). This variation was most likely influenced by the fact that the analysed speech was spontaneous, and therefore less controlled than e.g. word lists, which control preceding and following sounds and to date have often been used in studies related to the effects of the L2 on the L1 (see for example de Leeuw et al., 2013, 2017; Major, 1992; Mayr et al., 2012). Note that the random factors of preceding and following sounds were often significant in the linear mixed models, which was unsurprising given the spontaneous nature of the recordings. However, future research into the relationship between specific phonetic contexts and target variables may prove to be fruitful, i.e. it may be the case that the preponderance of particular contexts at certain recording times adds to an explanation of changes in speech over time. However, with regard to the lateral, there was a darkening over time, even though more laterals occurred in onset position after her move to Las Vegas than prior to her move, and, moreover, position in syllable was not a significant fixed effect.

The wide range of variation may also have arisen due to recency of native language exposure, as found in Sancier and Fowler (1997). For example, if SG had only recently returned to Germany when a specific recording took place, it may have been possible to see *more* L2 effects on the L1 than had the recording taken place after she had already stayed in Germany for a longer period of time. Although most of the recordings were made in Germany, and the year of the interviews was known, it was not known, for example, at what point the interview was made during her stay in

Germany. Such short-term effects of ambient language exposure may have counter-acted or even enhanced any long-term effects, which might have been evidenced had SG returned less frequently to Germany (see de Bot et al., 2007; de Bot & Schrauf, 2010; de Leeuw, Opitz, et al., 2013 in relation to the emphasis on short and long term changes in native speech with regard to Dynamic Systems Theory, as well as Paradis, 2004, 2007 in relation to language exposure influencing language production with regard to the Activation Threshold Hypothesis). However, it is likewise possible that the frequency of SG's visits may have made L2 effects on the L1 *more* likely as it has also been found that interaction may be more prevalent where dual activation occurs commonly (Mora, Keidel, & Flege, 2015), although it is not known how strictly German and English were separated during SG's visits to Germany.

Moreover, it may be that SG participated in sound changes *already* occurring in Standard German, and that her /l/, /i/ and *maxf0* changed as a result of these more general sound changes occurring in Germany, which she participated in as well, given her frequent visits back to Germany, rather than her German being influenced by English L2 acquisition at the individual level. A number of studies have examined contact situations in which languages undergo phonological convergence (Bullock & Gerfen, 2004; Colantoni & Gurlekian, 2004; Heselwood & McChrystal, 1999; Mayr, Morris, Mennen, & Williams, 2015), and as English is acquired *en masse* in German schools, it may be that this has influenced the German language more generally in Germany and that SG participated in this sound change. However, the author is not aware of studies documenting sound changes in Standard German with regard to changes in the front-back dimension of /l/ and /i/, nor with regard to increases in *maxf0*, and this possibility is therefore not considered likely in the current study, although such general language change phenomena would be important to consider in future research examining L1 changes in immigrant populations.

In addition to recency of language exposure effects, the variation in the segmental and prosodic variables of SG may also have arisen due to potentially different levels of formality in the interviews, for example, whether she already knew her interviewer well, and felt relaxed with him or her. Again, it was impossible to deduce this information from the recordings of her spontaneous speech, but previous cross-sectional research suggests that level of formality influences phonetic attrition with more formal settings eliciting less phonetic attrition than informal settings (Major, 1992; see also Shockey, 1984 with regard to new dialect acquisition).

Moreover, there is a growing body of research which suggests that heritage language markers may be retained in second generation speakers to fulfil socio-indexical functions on the part of the heritage language speakers (Alam & Stuart-Smith, 2011; Heselwood & McChrystal, 1999, 2000; Kirkham, 2011; Sharma & Sankaran, 2011) and some preliminary studies which suggest that even in first generation late bilingual immigrants, general attrition processes (i.e. the L2 influencing the L1) are influenced by socio-indexical factors (de Leeuw, 2019; Passoni, Mehrabi, Levon, & de Leeuw, 2018). It may be that the variation evidenced in the speech of SG was in part influenced by socio-indexical factors, potentially related to her interviewer, as well as the wider audience body she may have been targeting in her interviews. Nonetheless, although variation in the recordings was reported, it is interpreted that even with regular visits back to Germany, the effects of English on her German native speech were apparent, i.e. over time there was a significant increase in *maxf0*; significant decrease of F2 in /l/; and significant increase of F2 in /i/.

The *intrapersonal* variation in the spontaneous speech of SG, potentially due to recency effects, level of formality and / or socio-indexical factors, has implications on previous group cross-sectional research into the effects of the L2 on the L1, which often reports a high degree of *interpersonal* variation amongst late bilinguals. In almost all research into the effects of either a new language on native language pronunciation (Bergmann et al., 2016; de Leeuw et al., 2012, 2010,

2017; de Leeuw, Mennen, et al., 2013; Flege & Eefting, 1987; Hopp & Schmid, 2013; Major, 1992; Mennen, 2004; Mora et al., 2015; Tobin et al., 2017; Ulbrich & Ordin, 2014), or a new dialect on native dialect pronunciation (Munro et al., 1999; Shockey, 1984), as well as group longitudinal research into the effects of new dialect acquisition on the native dialect (Evans & Iverson, 2007; Sankoff, 2004), *interpersonal* variation has been reported: some participants evidence the analysed effects, some do not, and some only do so to a moderate extent. If the findings of SG are considered in relation to these group studies, it seems plausible that *intrapersonal* variation may have fed into the *interpersonal* variation. For example, often when interpreting interpersonal variation, age of acquisition and length of residence are investigated as potential factors which may impact the influence of L2 influence on the L1, but, at least within adults, most research shows that these factors do not significantly influence the effects on the L1, e.g. it does not appear to be the case that the longer a late bilingual resides in an L2 country, the more likely he or she is to undergo phonetic attrition, and it is likewise often found that within late adult bilinguals, the effects of age of L2 acquisition are weak to non-existing (de Leeuw, 2009; Hopp & Schmid, 2013; Schmid, 2011). It may be that the *intrapersonal* variation explains the observed *interpersonal* variation: those late bilinguals displaying strong effects of the L2 on the L1 in group studies did so *at that particular time of testing*, and those displaying weak or no effects of the L2 on the L1 did so *at that particular time of testing*, perhaps due to e.g. recency of exposure to the L1 and the L2, rather than due to fixed factors such as age of acquisition and length of residence. It may be prudent for future studies to focus on short as well as long term effects of the L2 on the L1 in order to explain native speech plasticity over the lifespan, which would likewise bring together research into shorter term phonetic drift (Chang, 2012, 2013; Sancier & Fowler, 1997; Tobin et al., 2017) as well as longer term phonetic attrition (Bergmann et al., 2016; de Leeuw et al., 2012, 2010, 2017; de Leeuw, Mennen, et al., 2013; Flege & Eefting, 1987; Hopp & Schmid, 2013; Major, 1992; Mayr et al., 2012; Mennen, 2004; Ulbrich & Ordin, 2014). Likewise, examining the effects of language mode on speech production would also

potentially prove to be informative (Amengual, 2018; Antoniou, Tyler, & Best, 2012; Simonet, 2014). Such investigations would need to ensure that the repeated testing of variables would not disturb the “natural course of the process [the test] hope[s] to track down” (Jaspaert & Kroon, 1989, p. 81), but there is potential for innovative research in this field incorporating both short and long term effects of speech plasticity over the lifespan.

A secondary objective of this study was to investigate whether plasticity in the native speech of SG was evidenced uniformly across all variables examined, or whether certain variables were more likely to undergo change than others. The conclusion from the analysis of SG is that the variables studied did not evidence plasticity uniformly. As already mentioned, although not further reported, at the segmental level, neither /u/ nor /r/ evidenced significant changes over time, whilst both /i/ and /l/ changed significantly over time. Similarly, of the prosodic variables, only *maxf0* increased significantly, most likely as a result of L2 acquisition of English, but pitch level and pitch range were potentially more impacted by the natural biological effects of aging. These findings do not support the suggestion that cross-linguistic interactions operate at a system-wide level (as suggested by Chang, 2012; Guion, 2003; Mayr et al., 2012). Specifically, there was nothing to suggest from the current study that there was a general trend towards more open (higher F1) realisations (as found in Mayr et al., 2012). Instead, the F1 of /i/ *decreased* significantly over time; the F1 of /u/ did not change significantly; the F1 of /a/ *increased* significantly over time, but it is not unequivocal whether the latter was caused by natural aging effects or the influence of the L2 on the L1; and the F1 of /l/ *decreased* significantly over time. Accordingly, and as will be discussed with regard to the third objective of this investigation, these results align more consistently with the effects of biological aging than they do with the impact of the L2 on the L1, although in the research by Mayr et al. (2012), Chang (2012), and Guion (2003), age was a controlled variable, which increases the likelihood of the L2 having indeed systematically affected the L1, rather than aging

processes. Nevertheless, the findings into SG similarly do not report systematic changes into the front-back dimension: F2 frequency of /i/ significantly *increased* over time; whilst neither the F2 of /a/ nor /u/ significantly changed over time; and the F2 of /l/ significantly *decreased* over time. Considering both the segmental and prosodic variables, these findings appear to verify the understanding that the production of native speech patterns, as measured in segmental and prosodic variables, are influenced *specifically* by increased exposure to their L2 *counterparts*, and that not all variables are influenced uniformly to the same degree. Accordingly, these findings could align more consistently with research which has shown that specific L1 variables are more prone to being influenced by a new language or dialect due to socio-indexical marking, as reported in Sankoff (2004) and Bergmann et al. (2016), which has also been reported in the L2 of heritage language speakers (Heselwood & McChrystal, 1999, 2000; Kirkham, 2011; Sharma & Sankaran, 2011). This is not to say that some kind of systematic change does not occur at all, e.g. in the form of change to an L1 articulatory setting (Laver, 1980; Mennen et al., 2010), but it is well established that different linguistic variables have different social meaning (e.g. stereotypes, markers and indicators, Labov, 1971), so it seems reasonable to assume that different L1 phonetic variables may be affected differently by their L2 counterparts dependent on their social meaning, as reported in Sankoff (2004), and potentially due to the perceptual similarity between L1 and L2 counterparts (Best, 1995; Escudero, 2005; Flege, 1995; Flege, 1987). Further longitudinal research examining a greater number of participants, incorporating the analysis of numerous phonetic variables which differ in social meaning and phonetic similarity may make headway on the question of whether plasticity of native speech occurs systematically over phonetic variables within a particular language, or whether it occurs dependent upon the individual variables, the latter of which the current investigation appears to suggest.

Finally, with regard to the third objective, these findings into plasticity of spontaneous native speech as a result of acquisition of L2 counterparts were entangled with the effects of biological aging. As predicted by previous longitudinal research (Reubold & Harrington, 2015, 2017; Reubold et al., 2010), the F1 of /i/ and /l/ decreased over time, whereas the F1 of /a/ increased over time, which was potentially amplified as a result of English L2 acquisition. This is to say that, particularly with regard to F1, aging effects appeared to either counteract any potential influence brought about by SG's acquisition of English segments, or amplify changes in her native speech. Particularly with regard to changes in the F1 as a result of biological aging over time, the findings from the current investigation support previous longitudinal research which suggests that in high vowels F1 decreases whilst in low values F1 increases, thereby expanding the vertical vowel space as the vocal tract ages (Reubold & Harrington, 2015, 2017; Reubold et al., 2010). Interestingly, the recordings of SG were made when she was much younger than the participants in the Reubold et al. research, therefore suggesting that the vowel space might begin to change already in early adulthood as a result of natural aging process. Accordingly, the results of SG do not align with those of Dagmar Berghoff, who did not exhibit any F1 aging effects until 56 years of age (Reubold & Harrington, 2017), potentially as a result of Berghoff's extensive professional voice training, which SG would not have undergone to the same extent given their different professions. Again, the current results therefore suggest that aging effects in the untrained voice might start already in early adulthood, and in the case of SG, be intertwined with L2 acquisition of English counterparts. Similarly, with regard to prosody, although it was expected that over time mean f_0 would have increased as a result of English acquisition of prosody, the more powerful effect appeared to be that of natural aging processes and, instead, a decrease in mean f_0 was evidenced in the speech of SG. It is therefore all the more striking that $maxf_0$ increased over time, which is suggested to indicate plasticity in the speech of SG as a result of English L2 acquisition of prosody. It would also be interesting to examine this prosodic effect from the perspective of intonational phonology (i.e., whether/how there may be some effects

on the actual tone-segment alignment patterns and intonational composition), rather than solely examining long-term distributional effects (see e.g. Graham & Post, 2018; Grice et al., 2017; Leemann et al., 2018) in order to further our understanding phonetics/phonology of bilinguals in connection with fine-grained phonetic detail of intonational structure.

In order to tease apart the longitudinal effects of biological aging and plasticity of native speech as a result of late L2 acquisition, it would be necessary to follow both bilingual and monolingual speakers over time, and compare their progression. For example, it could be that although the *f0* of SG decreased over time, it may have decreased *less* over time than had she not learned English as an L2. Likewise, although her *80%Range* narrowed over time, most probably as result of aging effects, had she not been immersed in English as an L2 in Las Vegas, it may have narrowed even *more*. Such questions can only be answered through larger studies, which track both monolinguals and bilinguals over time, whilst bearing in mind the effects of repeated testing of variables (Jaspaert & Kroon, 1989). As it stands, through investigating a single late bilingual over the course of time, the current study has been able to reveal plasticity in native speech which is interpreted to be a result of L2 acquisition in a few selected variables (*maxf0*, indicating a significant increase in maximum pitch excursions over time; F2 of /l/, indicating a significant darkening of /l/ over time; F2 of /i/, indicating significant fronting of /i/ over time), whilst in other variables, there was no effect, or the effect was potentially overridden by aging effects.

Nevertheless, as previously discussed, much cross-sectional research into monolinguals relies on the premise that once a language is acquired during childhood, it will not readily be altered by subsequent input (see e.g. Labov, 2006). The current findings strengthen the case for adult change rather than stability through examining native speech in the late German – English bilingual of SG over a timeframe of four decades. Together with other longitudinal research into monolingual adults (Evans & Iverson, 2007; Harrington, 2006; Reubold & Harrington, 2015, 2017; Reubold et al., 2010;

Sankoff, 2004), as well as bilingual adults (Chang, 2012, 2013; Giesbers, 1997; Oh et al., 2011; Sancier & Fowler, 1997; Tobin et al., 2017), the study shows that, if at all, one must proceed with caution when deducing an individual's earlier native speech patterns from his or her present adult speech patterns, and, therefore, likewise when deducing a community's childhood speech patterns from the same community's adult speech patterns.

In sum, although this study was only based on a single individual, and it is of course necessary to collect further longitudinal data to make unequivocal conclusions, the findings are interpreted to strengthen “the case for adult change rather than stability” (Labov, 2006, p. 501). They do so by revealing that L2 counterparts influence native speech phonetic variables at both segmental and prosodic levels, and that these changes are intertwined with biologically induced age-based changes. Moreover, the findings reveal that individual phonetic variables follow different trajectories within the same individual. It therefore seems compelling to continue to incorporate bilingual research into our understanding of speech plasticity, as experienced by the individual, as well as change within the community. Such studies into bilinguals will enhance our understanding of continued speech development post adolescence, and therefore provide a meaningful window into our understanding of human speech, language and cognition across the lifespan.

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